Hands on Exercises: Dosimetry & Shielding

1. What is the gamma dose rate from a 100 MBq source of Co-60 at 2m distance? (8.4 µSv/h)

2. A ^{60}Co gamma ray irradiation containing a 2TBq source is directed at a 30 cm thick concrete wall. The wall is situated at 7.5 m from the source. What the exposure rate behind the wall? (1.17 mGy/h)

3. Regulation impose an exposure rate outside the room of 7.5 µSv/h max. What thickness of wall would we then need? (75 cm)

4. We want to restrict the exposure rate inside the room (@1m from the irradiator) to 10 µSv/h using lead. Calculate the required thickness. (20 cm)

5. ^{99m}Tc is used in radioactive isotope medical tests, for example as a radioactive tracer that medical equipment can detect in the body. It is well suited to the role because it emits readily detectable 140 keV gamma rays, and it has a short half-life of 6.01 hours (meaning it has almost completely decayed to ^{99}Tc in 24 hours). A patient is injected 30 mCi of ^{99m}Tc. He is considered as an unshielded source during the time there is radioactivity in his body. Thus the staff is exposed to radiation. What is the equivalent dose rate that a staff member can be exposed to? (medium is tissue, 1 cm thick @1 m distance) (16.5 µSv/h)

6. Question from the Nucleonica forum – see next page

6. Question from the Nucleonica Forum

Dear Ladies and Gentlemen, just a question: why if I evaluate the gamma dose with the following composition (expressed in %):

Am241 31.46
Am242M 2.95
Am243 20.06
Np237 33.60
Cm242 0.01
Cm243 0.13
Cm244 9.36
Cm245 2.42

Looking at gamma rays dose I get a contribution from Am-242m of ca. 47%??? It appears a little bit strange, as Am-242m emits only few low energy gammas (and in fact its corresponding isotopic power is low). Should it be a bug?
I performed the decay calculation on a 100 grams composition, after 1 second (all other numbers were left as default).
I am trying to evaluate it in order to assess the radiological risk in different keypoints of a fuel cycle (fabrication and reprocessing plants, disposal, etc.).
Thank you.

Vincenzo Romanello

6. Reply to Question

Vincenzo,

thanks for your interesting question.

First of all you can do a Dosimetry & Shielding calculation for the single nuclide Am242m with a mass of 2.95g. You will see that this gives a dose rate at 1m of 2.24e4 µSv/h (as you correctlty say this is almost half the total gamma dose rate for the whole mixture).

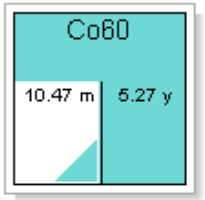
When you look at the dose contributions from each individual gamma ray, you see that the most important contribution come from the Am242m line at 15.2 keV (X-ray).

Now, if you look at the Options (in the D&S module), you will see that the threshold energy used in the calculation is 15 keV. The reason for this is that photons with energies below 15 keV are normally absorbed in the outer layers of the skin. It just happens that Am232m has an X-ray at just above this value i.e. 15.2 keV. This makes a large contribution to the dose rate if counted in the calculation. Further details on the Threshold Energy are given in the Nucleonica wiki at http://www.nucleonica.net/wiki/index...Options_Window

Now because it is very close to 15 keV, the Am242m photon at 15.2 keV will also be absorbed in the outer layers of the skin and so practically can be ignored in the calculation.

So you can do the following: 1) increase the threshold to 16 keV or 2) switch off the X-rays in the Options. If you do this you will see that the dose rate for 2.95 g Am242m decreases from 2.24e4 to 57.6 µSv/hr!

In summary, the Nucleonica calculations are correct - there is no bug. However, in all calculations, you must be aware that the threshold energy is 15 keV. If you have a nuclide with gamma or X-ray photon energy near to this value - this should be eliminated from the calculation (since it is absorbed in the outer layers of the skin).



Dosimetry and Shielding

27 Cobalt

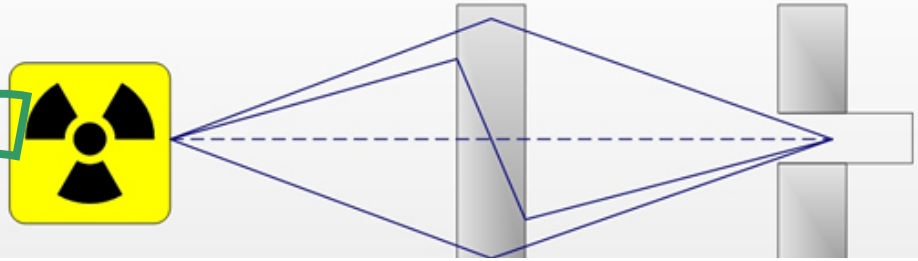
Questions, remarks, suggestions can be posted in the **forum**

Current Chart: Karlsruhe

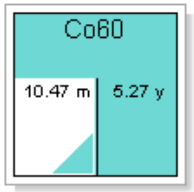
Element: Co Mass: 60 Nuclide Mixtures Selector

Dosimetry and Shielding | Dose rate/Thickness graph | Options

Source strength	Shielding material		Dose rate (µSv/h)
Activity(Bq) 2e12	Concrete	30 cm	???



Half-Value Shield Thickness(cm)	1.31E+01
Tenth-Value Shield Thickness(cm)	3.05E+01
Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h)	3.37E-01
Gamma Dose Rate (µSv/h)	**1.17E+03**
Effective Build-up factor	6.81E+00
Effective Number of Mean Free Paths (µ·d)	4.17E+00



Dosimetry and Shielding

27 Cobalt

Current Chart: Karlsruhe

Questions, remarks, suggestions can be posted in the **forum**

Elem

Co

D(

Dosimetry and Shielding | Dose rate/Thickness graph | Options

Dosimetry and Shielding Settings

Energy range option:

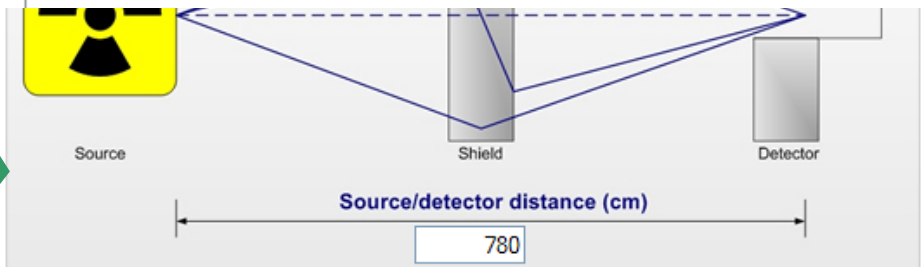
- ○ Only Gamma
- ○ Only X-rays
- ◉ Gamma and X-rays
- ☑ Threshold set

Mode of operation option:

- ○ Gamma Dose Rate
- ◉ Shield Thickness
- ○ Source Strength

Threshold energy (keV): 15

Result Detail option: ☐ Show Nuclides



Start | Reset

Element: Mass:

Co 60 Nuclide Mixtures Selector

Dosimetry and Shielding | Dose rate/Thickness graph | Options

Source strength

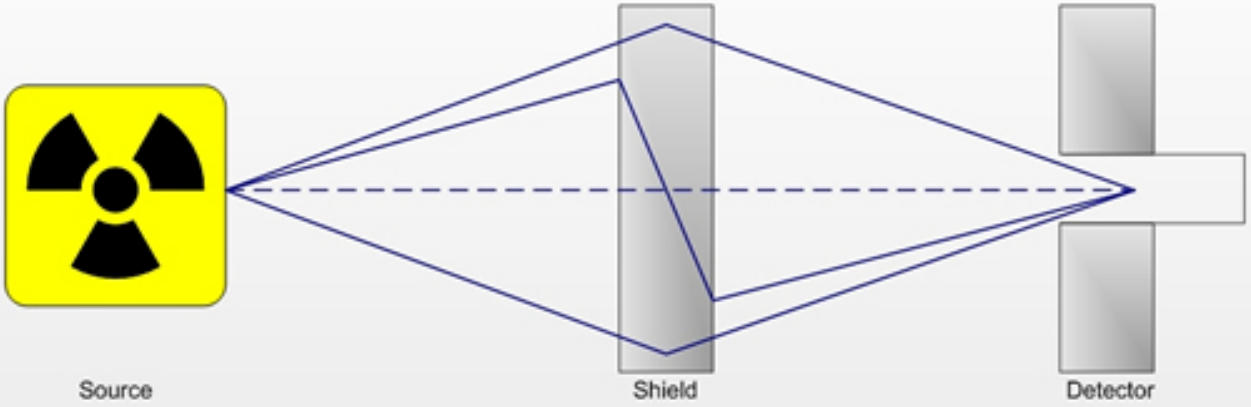
Activity(Bq) 2e12

Shielding material

Pb 19.77 cm

Dose rate (µSv/h)

10



Source/detector distance (cm)

100

Element: Mass:

Tc | 99 m | Nuclide Mixtures Selector

Dosimetry and Shielding | Dose rate/Thickness graph | Options

Source strength

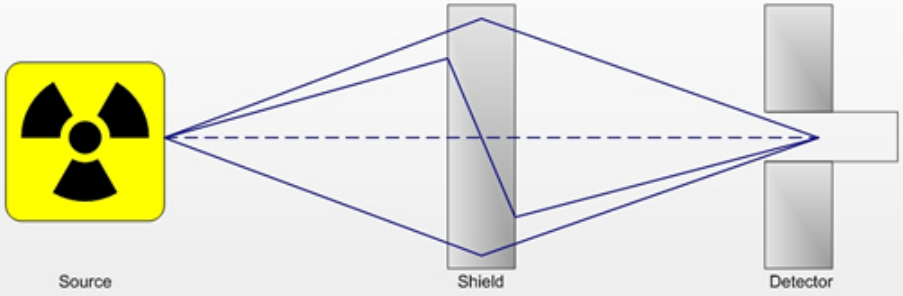
Activity(Ci) 3e-2

Shielding material

Tissue 1 cm

Dose rate (μSv/h)

1.65E+01



Source/detector distance (cm)

100

Start | Reset

Half-Value Shield Thickness(cm)	2.89E+00
Tenth-Value Shield Thickness(cm)	1.27E+01
Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h)	2.09E-02
Gamma Dose Rate (μSv/h)	**1.65E+01**
Effective Build-up factor	1.00E+00
Effective Number of Mean Free Paths (μ·d)	3.00E-01

Distance From Patient (cm)	Exposure Rate (mR/h per mCi)	Exposure for Typical Procedures (mR)† Thallium (3.5 mCi)	^{99m}Tc (30 mCi)
1	698	1,629	13,960
5	28	65	558
15	3	7	60
30	0.8	1.8	16
100	0.07	0.2	1.4

JACC Vol. 31, No. 4
March 15, 1998:892–913